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QUARTERLY PROGRESS REPORT

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Report No. 72-101-2
Contract NASW-417

Bellcomm

FINAL QUARTERLY PROGRESS REPORT

January February March

1972

I. M. Ross
President

Bellcomm
955 L'Enfant Plaza North, S. W., Washington, D. C. 20024

Report No. 72-101-2
Contract NASW-417

FINAL QUARTERLY PROGRESS REPORT

ABSTRACT

The activities of Bellcomm during the quarter ending March 31, 1972 are summarized. Reference is made to reports and memoranda issued during this period covering particular technical studies. This completes the reporting of all work under Contract NASW-417.

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FINAL QUARTERLY PROGRESS REPORT

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APOLLO/SATURN SYSTEMS ENGINEERING

Mission Planning

Mission Assignments

A revised issue of the Apollo Flight Mission Assignments document was prepared for the Apollo Program Director. Following review and approval by the Associate Administrator for Manned Space Flight, the document was distributed. This issue identified Taurus-Littrow as the landing site for Apollo 17 and updated mission parameters for Apollo 16 and 17.

Mission Analysis

Apollo 16

The Apollo 16 Mission Requirements Document, the Flight Plan, and the Final Mission Rules were reviewed for the Apollo Program Office. Discussions were held with the Centers to resolve the omission of several rules lost in a major format revision of the Mission Rules. A list of the rules in this category and their final status was prepared for the Apollo Mission Director.

The sensitivity of land landing probability to various space vehicle and environmental factors was examined for the Apollo Program Director. The analysis showed that the wind direction and magnitude was the strongest contributor to land landing for an abort after the first 61 seconds ground elapsed time (GET). For aborts from a nominal launch vehicle trajectory the probability of land landing after 61 seconds GET drops below 1%.(1) If an engine-out occurs before 61 seconds the probability of land landing in the worst case using statistical winds remains about 1% for aborts up until about 140 seconds GET.

The Apollo 16 lunar surface traverse plan was examined to determine potential contingency situations which might merit advance consideration. The results were presented to the Apollo Program Office.

The slopes which will be encountered by the Lunar Roving Vehicle (LRV) during descent from Stone Mountain at Descartes were computed. These data were forwarded to the Apollo Program Office to support a review of the LRV braking capability during the descent from Stone Mountain. A study was performed to determine the visibility of Sugarloaf Mountain, a high peak north of the landing site, during the traverse at Descartes.(2) It was determined that the peak will be visible from most of the

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(1) Land Landing Probability for LES Abort Following An Engine Out, Memorandum for File, D. G. Estberg, March 31, 1972.

(2) Visibility of Sugarloaf During Traverse at Descartes, Memorandum for File, H. F. Connor, February 7, 1972.

traverse area, and that it may be a useful landmark to identify the intended route from Palmetto to North Ray Craters.

The LM descent stage battery budgets for Apollo 15 and Apollo 16 were reviewed and compared for theApollo Program Director. A revision was incoroprated into the budgeting technique subsequent to the Apollo 15 mission to improve the accuracy with which certain cycled loads can be estimated. As a consequence of this improvement, the Apollo 16 budget will have approximately the same predicted power margin as Apollo 15 despite a larger predicted surface usage.

An assessment was performed of a proposed excursion during EVA-I to view terrain north of the landing site which would later be traversed during EVA-III.[3] It was determined that terrain in the immediate vicinity of North Ray and Ravine Craters could be viewed with an excursion slightly in excess of one kilometer to the north. A view of significant portions of the traverse routes would require an excursion two and one-quarter kilometers to the north.

The effects of poor trafficability in the area of North Ray Crater on the Apollo 16 surface traverses were examined.[4] If the terrain is impassible by the LRV, the crew would have to walk to the prime objectives in the area, therby increasing travel time and requiring deletion of some subsequent tasks and/or stations. It was found that the LRV can be left almost 800 meters from the rim of North Ray and still allow the crew to walk to the rim without exceeding the return limit of the oxygen purge system.

The effects of the LRV parking attitude on the thermal performance of the LCRU and LRV batteries were examined.[5] The analysis showed that some deviation from a nominal parking attitude would be acceptable but that the magnitude of the deviation would have to be determined in real-time during the mission.

Performance margins were examined for the April, 1972 launch opportunities. The launch window for the T+24 opportunity was found to be less than one hour if sufficient SPS margins were maintained to provide expeditious return to earth following a LM rescue. These findings were presented to the Apollo Program Director, and a decision was made not to use the T+24 opportunity in April. Performance scans were also made and presented to the Apollo Program Director for potential July, 1972 launch opportunities.

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(3) Visibility of Northern Areas at Descartes from a Proposed Excursion During EVA I, Memorandum for File, H.F. Connor, February 15, 1972.

(4) Effects of Poor Trafficability at North Ray Crater on Apollo 16 Geology Traverses, Memorandum for File, K.P. Klaasen, March 31, 1972.

(5) Effects of LRV Parking Attitude on Thermal Performance of the LCRU and LRV Batteries, Memorandum for File, A.S. Haron, February 29, 1972.

A comparison was made between the performance predictions for the Apollo 15 and Apollo 16 launch vehicle S-IVB stages. (6) The predicted performance of the Apollo 16 S-IVB stage was found to be better than that of Apollo 15 because of known engine performance differences and because of an update in the MSFC performance prediction program after consistently better-than-predicted performance experience on previous missions.

A presentation was made to the Apollo Program Director on the Apollo 16 launch vehicle performance capability covering the effects of alternate loading procedures and the effects of engine-out malfunctions. Alternating loading could decrease payload capability a maximum of about 1000 pounds; however, capability would still be above Apollo 16 vehicle 2σ performance requirement. Engine-out capability is slightly improved over that of Apollo 15 due mainly to a reduced TLI commit criterion, greater propellant reserves and new tilt arrest logic in the S-IC flight program.

The Apollo 16 S-IVB LH_2 depletion sensor arming time was examined at the request of the Apollo Mission Director to determine whether a flight program logic change was required because of the new minimum predicted post-TLI apogee for acceptable TLI commit. Using Apollo 15 performance data, it was determined that the presently programmed arming time was satisfactory for the new minimum apogee limit. A recommendation was subsequently made to change the arming time when the higher performance rating of the Apollo 16 launch vehicle became known.

Previous analysis of the lighting conditions prevailing at lunar landing for the Apollo 16 T+24 opportunities established acceptable visibility for sun elevation angles of up to 19 degrees. With the slip of the prime Apollo 16 launch date to April, 1972, the T+24 opportunity in June was examined since a sun elevation of 23 degrees or more may be encountered with this opportunity. Although crew safety is not a factor per se, the ability of the LM crew to land in a predesignated area is impaired by the higher sun angles.

Computer-generated views showing the regions visible to the Commander and to the LM Pilot during the descent to the Descartes site were published. (7) Shaded versions of these scenes have also been prepared in which the relative brightness of the surface features is indicated by the shading of the scene. (8) A special view into North Ray Crater as seen from EVA Station 11 has also been published,(9)

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(6) AS-511 S-IVB Performance Prediction Compared to AS-510, Memorandum for File, K. P. Klaasen, January 20, 1972.

(7) Two Computer-Generated Views of the Descartes Landing Area from the LM During Descent, Memorandum for File, S. C. Wynn, January 19, 1972.

(8) Computer-Generated Views Showing Surface Brightness Variations of the Descartes Landing Area from the LM During Descent, Memorandum for File, S. C. Wynn, February 29, 1972.

(9) View of North Ray, Memorandum for File, S. B. Watson, March 31, 1972.

and an index has been issued of all computer-generated surface scenes prepared at Bellcomm for the Descartes area.[10] This latter memorandum contains several new surface scenes as well as a chart showing the location and field-of-view of every surface scene generated.

Apollo 17

The data bank of SPS ΔV requirements for missions to the candidate Apollo 17 sites, Alphonsus and Taurus-Littrow, was extended to include March and April of 1972. It was found that both sites would continue to be accessible. However, an adjustment in the approach azimuth to Taurus-Littrow site would probably be necessary if a slip in launch data did occur. All opportunities to Alphonsus would be available with an approach azimuth of -83°. Discussions with MSC personnel regarding SPS ΔV requirements for Apollo 17 were continued in preparation for the February 11 meeting of the Apollo Site Selection Board. The data were also made available to the Apollo Program Director in advance of the meeting.

Oblique views of the Taurus-Littrow and Hadley-Apennines sites were prepared from topographic data and were made available to the Apollo Program Office to support an assessment of the approach and landing problems at Taurus-Littrow.

A preliminary assessment was made of shadow areas near the Taurus-Littrow landing site at sun elevation angles of 5.8 and 7.5 degrees. Preliminary topographic data from the USGS were used. It was shown that a portion of the landing ellipse may be in shadow at the time of touchdown, depending upon the exact sun elevation angle and the ellipse size.

Space Vehicle Performance

The pre-mission budgeting and real-time monitoring of LM descent propellant consumption were examined and explained with a graphical analysis emphasizing the relationships of propellants consumed and propellants remaining with time.[11] Apollo 15 budgeting and performance data were used for the analysis. It was concluded that the budget predictions were accurate and that the real-time monitoring procedures provide the required assurance of crew safety and adequately support a successful landing.

The boundary for aborts from descent using only the ascent propulsion system (APS) was studied to determine how the flight experience of Apollo 15 compared with other lunar landing missions. The analysis showed that all actual trajectories had more time below this boundary than was shown for automatic descent in the

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(10) Additional Computer Generated Panoramas of the Descartes Terrain and an Index to all Available Scenes, Memorandum for File, G. S. Taylor, March 3, 1972.

(11) Apollo 15 LM Descent Propulsion Budgeting and Performance, Memorandum for File, W.W. Ennis, March 31, 1972.

operational trajectories. However, this practice seems to be a result of normal manual piloting procedures when looling for a suitably smooth touchdown point. A rough rule of thumb for the height of the APS abort boundary in feet is 80 plus 10 times the descent rate (in feet per second).

Monthly weight and performance analyses were presented for the Apollo Program Director's review.

Guidance and Navigation

Presentations on the Bellcomm-developed selenodesy method were given at the Manned Spacecraft Center and the Jet Propulsion Laboratory, and copies of the computer programs which embody the method were delivered to MSC and JPL. A complete description of the lunar gravity estimation process was completed.(12) Two papers describing the method and presenting the results obtained have been submitted to the journals Celestial Mechanics and The Moon.

General

The program TOPORAMA and the data base used to produce the computer-generated scenes of the Descartes landing area were delivered to and tested at MSC. Versions of the program to plot both on the SC4020 and on the Gerber plotters were included. A draft of the program user's guide was provided.

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(12) An Empirical Method for Determining the Lunar Gravity Field, TM-72-2014-1, A. J. Ferrari, February 28, 1972.

Scientific Studies

Apollo 17 Site Selection

The local and regional geology of the potential Apollo 17 landing sites were examined in preparation for site selection. The geology of the Taurus-Littrow region was studied in detail and the geologic results were compared with ground based IR and radar studies. The scientific advantages and disadvantages of each potential site were evaluated. The extent of lunar surface coverage for the orbital experiments for each potential site was determined, and the extent of the photographic overlap with that obtained in Apollo 15 and 16 was determined.

Science considerations bearing on site selection were reviewed at a meeting of the Ad Hoc Site Evaluation Committee. The Committee agreed that Taurus-Littrow should be recommended to the Apollo Site Selection Board (ASSB) as the Apollo 17 site with Gassendi as an alternate. A subsequent meeting was held at MSC with operations personnel to resolve problems of site accessibility. The Ad Hoc recommendations were presented to the Science Working Panel (SWP) on February 8, 1972, and to the ASSB on February 11, 1972. The ASSB concurred in the recommendation of Taurus-Littrow as the Apollo 17 site and the recommendation was subsequently approved by the Associate Administrator for Manned Space Flight.

Apollo Mission Support

Apollo 16

The geology of the Descartes landing area was studied and a geologic description of the site was prepared for inclusion in the Mission Implementation Plan.

Work continued on planning the geologic traverses, including the assignment of priorities for the sampling at the various work stations. The crew was briefed on the traverse planning on six occasions, and the prime and backup crews were accompanied on a field trip to acquaint them with the geology of comparable terrestrial analogs. The SWP was briefed on the traverse planning on February 7, and the Apollo Program Director was briefed twice on the same subject.

Surface EVA simulations were attended to acquaint the crew with details of the traverses. A cuff-check list was developed for the traverses and the crew was acquainted with the tasks.

Contingency plans for the geologic traverses have been developed for cases where the LRV is inoperable, and also where the LRV is operable but an EVA must be shortened. The prime and backup crews, the SWP, and the Apollo Program Director have been briefed on the contingency plans.

The Command Module photographic targets were identified and the list was transmitted to MSC. Twenty-six lunar surface targets were identified for photography with the Hasselblad Camera equipped with the 250 mm lens, using both black-and-white and color film.

Meetings have been held with the flight planners to further define particular photographic plans, including Earthshine photography. The plans for the Mapping and Panoramic Cameras have been reviewed and comments provided to MSC.

The Preliminary Flight Plan for Apollo 16 was reviewed to determine the positions of the SIM Bay experiment booms during photographic passes. The recommendation was made to retract the booms on revolution 60 in order that all prime mapping photographic passes should have an unencumbered field-of-view.

The coverage of the Apollo 16 Panoramic and Mapping Camera photography was investigated and the extent of overlap of similar photography on Apollo 15 was determined.(13) It was concluded that approximabely 40% of the area overflown on Apollo 16 between LOI and TEI will also have been overflown on Apollo 15; similarly, approximately 25% of the lunar surface areas photographed on Apollo 16 will also have been photographed on Apollo 15.

Photographic targets were selected for the CM and SM cameras for the case where lunar orbit insertion deviated considerably from that planned. Two hundred photographic targets were identified between 50°N and 50°S within the sunlit portion of the mission groundtracks.

At the request of NASA/MAL the "Lunar Orbital Experiments Summary" document was updated to reflect additions to the Apollo 16 orbital experiment complement and to incorporate some preliminary experiment data from Apollo 15.

The preliminary program for geologic observation from lunar orbit was prepared. The program was designed to accommodate the particular mission tasks as well as the expressed desires of the crew.

Apollo 17

The local and regional geology of the Taurus-Littrow site was studied and a written summary was prepared for inclusion in the Mission Implementation Plan. Preliminary geologic traverses were prepared including the operation of the traverse experiments. The crew was briefed on these plans and related training of the crew has been initiated.

Lunar Orbital Photographic Products

The initial mapping requirements for Apollo lunar photography was evaluated. It was recommended that the full capability inherent in both the Metric and Panoramic Camera systems be utilized, and that the map scales be standardized to permit easier cross-correlation. It was suggested that the existing 1:5,000,000

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(13) Photographic Coverage on Apollo 16, Memorandum for File, W. L. Piotrowski, January 18, 1972.

shaded relief map not be revised unless the improved imagery from Apollo photography presents substantial differences at the scale to which the map is constructed.

Lunar Surface EVA Photography

The Apollo 15 photography of Hadley Rille was studied from the standpoint of photographic contrast.(14) Prior to the Apollo 15 flight considerable variation in contrast was predicted. The predictions resulted in suggestions for specific targets either to be emphasized or ignored at various EVA photographic stations. The photographs appear to have satisfactory contrast, generally confirming the predictions. The general technique can be applied to Apollo 16 and 17 photography, and specific recommendations were made for application of these techniques.

Lunar Science Studies

Analysis of the Earthshine photography from Apollo 15 and the Near Terminator photography from Apollo 14 and Apollo 15 continued. A paper on this subject was presented at the Lunar Science Conference.(15) The paper emphasized the photometric results of Earthshine photography and suggested a need for explanation of the photographic results in terms of the physical property of the lunar surface material.

A paper on the "Geologic Conclusions from Apollo 15 Photography" was also presented at the conference.(16) An invited paper on the orbital science returns from Apollo 15(17) was presented to a joint meeting of the American Institute of Aeronautics and Astronautics and the American Astronautical Society on January 25, 1972.

Reports on "Visual Observations from Lunar Orbit"(18) and "The Cinder Field of the Taurus Mountains"(19) were prepared for inclusion in the Apollo 15 Preliminary Science Report to be published at NASA SP-289.

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(14) Lunar Surface EVA Photography of Hadley Rille -- Contrast as a Constraint, TM-72-2015-2, H.W. Radin, February 1, 1972.

(15) Earthshine and Near Terminator Photography Obtained on Apollo 15, D.D. Lloyd and J.W. Head, Third Lunar Science Conference Abstracts, 1972.

(16) Geologic Conclusions from Apollo 15 Photography, F. El-Baz, Third Lunar Science Conference Abstracts, 1972.

(17) Orbital Science Returns from Apollo 15, F. El-Baz, AIAA Transactions, 1972.

(18) Visual Observations from Lunar Orbit, F. El-Baz, A. M. Worden, Apollo 15 Preliminary Science Report, 1972.

(19) The Cinder Field of the Taurus Mountains, F. El-Baz, Apollo 15 Preliminary Science Report, 1972.

A study of the brightening of the lunar surface at the Apollo 15 landing point indicated that it may be due to densification of the uppermost soil due to the impingement of the descent engine exhaust gases.[20]

In collaboration with R. R. Hodges, Jr. and J. H. Hoffman (University of Texas at Dallas) a study was made of the capability to detect volcanism from lunar orbit. The study revealed that a sporadic release of large quantities of gas may be detected by an orbiting mass spectrometer such as those carried on the Apollo 15 and Apollo 16 missions. A paper on this study has been submitted to the Journal of Geophysical Research for publication.[21] The nature of a gaseous perturbation of the lunar atmosphere is discussed, and a lower bound is derived for the expected time between detected events. Quantitative assessment of this time is inferred from Apollo 15 data to be longer than the total time over which data has been accumulated.

Lunar Science Experiments

Bellcomm participated in the detailed reviews of both the orbital and surface science experiments for the J-missions - including reviews on the Lunar Surface UV Camera (S201), the Lunar Atmospheric Composition Experiment (S205), the Lunar Surface Gravimeter (S207), the Lunar Ejecta and Meteorites Experiment (LEAM), the Lunar Surface Soil Collector, and the Laser Altimeter.

The design and development of the Lunar Surface Soil Collector, scheduled for inclusion on Apollo 16, have been closely monitored to ensure that the device will adequately sample the desired surface layers. The status of the instrument was reported to the SWP on February 7, 1972. A review was made of soil potting techniques proposed for use on the Apollo 17 mission to collect the topmost lunar surface structure. The position taken before the SWP was that the technique, although promising, is not sufficiently advanced to give confidence that it could be developed in time for the mission.

A detailed analysis of the thermal design of the Traverse Gravimeter Experiment was made. All reasonable mission profiles were tested in time-dependent simulation studies and the design was found to be adequate. There is every expectation that this paper design can be physically realized, but some changes in parameters were checked to confirm that the design had adequate margins.

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(20) Surface Disturbances at the Apollo 15 Landing Site, N. W. Hinners and F. El-Baz, Apollo 15 Preliminary Science Report, 1972.

(21) Orbital Search for Lunar Volcanism, R. R. Hodges, Jr., J. H. Hoffman, T. T. J. Yeh, G. K. Chang, submitted to the Journal of Geophysical Research.

An investigation was made of the performance characteristics of the Pioneer and LEAM cosmic dust sensors. The uncertainty introduced into the determination of the orbital elements of the detected dust particles by the angular resolution of the sensors is expressed in terms of statistical deviation from mean calculated values. The probability for a given dispersion for each orbital element of observed particles was also calculated.

Solar Wind/Planetary Ionosphere Interaction

A study was completed on an ionosphere-solar wind interaction[22] using an electrodynamic model based on the existence of a low plasma below the anemopause, which is a solar wind current sheath analogous to the magnetopause. The results of the study have been submitted to Cosmic Electrodynamics for publication.

CSM Water Dump/SIDE H_2O^+ Readings

Based upon order of magnitude consideration for sublimation rates of ice crystals in space and for rates of dissociation and ionization of H_2O molecules it does not appear that Apollo 14 CSM dumps made on February 4, 5 and 6 were the source of the H_2O^+ readings reported by the Suprathermal Ion Detector Experiment (SIDE) on March 7, 1971.[23]

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(22) Interaction of the Solar Wind with a Planetary Ionosphere, TM-72-2015-1, W. R. Sill, J. L. Blank (Western Electric Research Center), January 25, 1972.

(23) Investigation of CSM Water Dumps as a Possible Source of the SIDE H_2O^+ Readings of March 7, 1971, Memorandum for File, R. J. Stern, March 31, 1972.

Flight Mechanics

A copy of the long term analytic trajectory generation program, VARPAR was obtained from Bell Telephone Laboratories in order to determine its possible usefulness in Skylab Mission Analysis.(24) It was found that VARPAR is capable of generating a 240 day Skylab trajectory in thirty seconds of CPU time on the Univac 1108. This compares quite favorably with the two hours plus time requirement of the currently used program. VARPAR trajectories were compared to actual earth satellite histories and were found to have a maximum error of 117 degrees in mean anomaly after 270 days - well within the dispersion to be expected from the uncertainty in drag. Trajectories generated by MSC and MSFC analytic programs were also compared to VARPAR trajectories. Here the uncertainty due to drag was ostensibly eliminated by using equivalent drag models and data. These MSC and MSFC trajectories differed in argument of latitude by a maximum of 0.6° and 51° respectively after 29 days of propagation.

The combined effect of long term periodic and secular perturbations was computed for the Skylab orbit using the VARPAR program.(25) The perturbations caused by oblateness, drag, and solar and lunar gravity were treated parametrically to show the relative magnitude of each effect. The orbit eccentricity and argument of perigee were shown to be affected most by the J2 and J3 terms of the oblateness perturbation. The semi-major axis is perturbed the most by drag which all but obscures the effects of the other perturbations. The right ascension of the ascending node is principally affected by the J2 oblateness harmonic. Finally, the orbit inclination is principally affected by the lunar-solar gravitational perturbations.

Electrical Power System

A performance analysis of the Skylab Electrical Power System for orbits that include and follow a set of Earth Resources Experiment passes was performed.(26) The primary effects on system performance of time varying sun-spacecraft geometry and solar array temperature were considered. Secondary effects of solar array coverslide reflection, radiation degradation, and solar array shadowing were not included.

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(24) Long Term Trajectory Generator with VARPAR, Memorandum for File, R. C. Purkey, February 28, 1972.

(25) Long Term Perturbations to the Skylab Orbit, Memorandum for File, R. C. Purkey, March 31, 1972.

(26) Skylab Electrical Power System Performance for the Earth Resources Mode, Memorandum for File, D. P. Woodard, February 15, 1972.

Numerical results for ATM and AM battery charge levels for several combinations of one and two-consecutive 60° and 120° true Z-LV passes that are centered at orbital noon or that begin at orbital sunrise were calculated. These results cover the range of Beta angles from 0° to 60°. For the cases considered, the Skylab Program constraint not to exceed 50% battery depth of discharge is not violated. Another constraint - that 30% of battery rated capacity remain in the batteries at all times - will rule out the two consecutive 120° sunrise passes midway in the SL-3 mission.

Attitude Control

A study has been completed of the equilibrium properties of the Skylab CMG rotation law.(27) The existence of multiple equilibria has been demonstrated for both two and three CMG cases. Necessary and sufficient conditions are given for equilibrium, and these conditions are used to develop methods of finding the equilibria.

The results appear to be useful for mission operations in the management of the CMG gimbal angles to minimize gimbal stop encounters. In some cases two equilibria can be rank ordered on the basis of their future potential for encountering a gimbal stop.

A graphical representation is given to display the range of gimbal angles consistent with the angular momentum constraint. Equilibria appear as points within the allowable set.

It is demonstrated that the rotation law minimizes a quadradic function of gimbal angles subject to the angular momentum constraint. An extension of this performance function to a moving or dynamic origin is given. This extension appears to be useful in leading to better transient behavior of the gimbal angles.

A computer program, SACSIM, was written to simulate spacecraft attitude hold and maneuver operations during various portions of the Skylab mission.(28) The program integrates up to 22 first order differential equations in evaluating spacecraft attitude and rate response to various disturbance and command torques. The intended uses of the program are to study various mission modes, to exercise and evaluate control moment gyroscope (CMG) laws (steering, rotation and distribution), and to investigate contingency modes where one or more CMG fails.

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(27) Equilibrium Properties of the Skylab CMG Rotation Law, TM-72-1022-2, B. D. Elrod, G. M. Anderson, March 31, 1972.

(28) User's Guide for SACSIM - Skylab Attitude Control Simulation, Memorandum for File, R. W. Grutzner, March 8, 1972.

Thermal Control

Several authors have contributed to the understanding of the thermal stratification in the Apollo and Skylab cryogenic oxygen tanks. However, thermally induced mixing has not been examined previously in sufficient detail. A study was made to formulate and solve the problem for cylindrical geometry, retaining all the thermodynamic parameters in the governing equations.(29) Fluid velocity waves of acoustic nature were found to occur. To enable study of the relatively slow thermodynamic process and the very fast fluid velocity waves while maintaining a tolerable real-time to computer-time ratio, a time scaling procedure was employed for solving the finite difference equations.

Experiments with a one-dimensional model of helium gas agreed well with published results. For the cylindrical oxygen tank, there is found to be appreciable thermally induced mixing, which has not been predicted by studies that have neglected fluid motion. Thus, stratification appears to be less severe than previously predicted.

Corona Problems

Work was completed on a long series of corona problems related to space vehicle and experiment hardware. A memorandum was written to summarize the recent history and current state of methods for preventing corona and voltage breakdown in space flight systems.(30) As the duration of missions has increased, the perferred means of corona prevention has changed from pressurization to equipment potting and evacuation.

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(29) Thermodynamic Flow of Super-Critical Oxygen in Zero-Gravity, TM-72-1022-1, V. Thuraisamy, March 20, 1972.

(30) State of Voltage Breakdown Prevention in Space Flight Systems, TM-72-2034-1, W. J. Benden, March 31, 1972.

ADVANCED MANNED MISSIONS SYSTEMS ENGINEERING

Manned Space Flight Experiments Program Studies

Task Order No. 36

A generic model for the use of Shuttle in sortie mode, based on the NASA Convair 990 airplane program, was developed and used to show that the reusable Space Shuttle can permit radical changes in earth orbital scientific and engineering activities, broadening both content and participation.(31) The principal investigators fly, operating their instruments, in a sortie module contained within the Shuttle payload bay. A fully mature Shuttle (circa 1985) is assumed. The model was tested against data from collateral studies in the disciplines of astronomy, cosmic ray astronomy, life sciences,(32) technology and general science, spacecraft development, and earth applications.(33)

Since cost is set by Shuttle launch cost and effectiveness by the number of investigators, a fairly large crew size is desirable. An arbitrary habitability limit (600 cu. ft/man) is eighteen; other considerations may lead to a compromise in the six to fifteen range. Overhead time - adaptation to space, set-up, redirection, and stowage - is uncertain but is surely several days, requiring a minimum flight duration somewhat over a week. There are specific arguments for longer duration in most disciplines, nearly doubling the potential activity between one and four week capabilities.

A presentation on the use of the Space Shuttle in the sortie mode was given to KSC personnel on March 10. Since the group at KSC plans to define typical sortie payloads in order to determine the cost of support facilities that will be needed, the presentation stressed hardware aspects of the Shuttle sortie activities.

Technical work under this task order was completed on January 31, 1972. The technical summary of work performed under the task order was issued on February 7, 1972.(34)

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(31) Use of Shuttle in Sortie Mode, TM-72-1011-3, G. T. Orrok, January 31, 1972.

(32) Use of Shuttle for Life Sciences, Memorandum for File, R. E. McGaughy, January 25, 1972.

(33) Earth Applications and the Space Shuttle, Memorandum for File, W. W. Elam, January 25, 1972.

(34) Technical Summary of Work Performed Under Task Order 36, Manned Space Flight Experiment Program Studies, W. W. Elam, G. T. Orrok, January 1 through December 31, 1971.

Advanced Technology

Task Order No. 37

A technique for rapid computation on a desk calculator of exit speed and exit flight path angle from any pass of a multi-pass aerobraking mission was developed.[35] The technique was used to analyze the effect of deviation of atmospheric density from predicted nominal values and the corresponding fuel requirements to allow correction of the trajectory on a two-pass aerobraking mission. It was estimated that a ΔV of approximately one ft/sec at apoapsis (approximately one pound of fuel for a 15,000 pound vehicle) would be necessary to correct for an atmosphere deviation of 10%.

Technical work under Task Order 37 was completed on January 31, 1972. The technical summary of work performed under the task order was issued on February 10, 1972.[36]

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(35) Analytic Modeling of an Aerobraking Pass, Memorandum for File, R. N. Kostoff, January 19, 1972.

(36) Technical Summary of Work Performed Under Task Order 37, Advanced Technology, H. S. London, G. T. Orrok, J. A. Schelke, January 1 through December 31, 1971.

GENERAL MISSION STUDIES

Available results of observation have shown that at nadir the brightness temperature of the sea surface at 19.35 GHz increases linearly with increasing wind speed. The computational results of a modified theoretical model(37) are in good agreement with the measurement results both at nadir and other angles. The model depicts that, for a fully developed sea driven by the wind with speed above 5 m/sec, the air in the transitional zone immediately above the air-sea interface is mixed with sea water droplets from bursting air bubbles. The droplet concentration has a profile tapering off to zero at a certain height. The dielectric constant of the inhomogeneous droplet profile is thus both a function of the height above the interface and the wind speed. Both the inhomogeneity effect and the possible attenuation effect of the droplet concentration have been considered.

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(37) The Brightness Temperature of the Air-Sea Interface at Microwave Frequencies, TM-72-1011-1, C. C. H. Tang, January 21, 1972.

SPECIAL TASK ENGINEERING STUDIES

Analysis of Haze Effects on Martian Surface Imagery

Task Order No. 35

Bellcomm supported the real-time mission operations of the Mariner '71 spacecraft through January 21, 1972. The unexpected presence of a major dust storm on Mars rendered useless the mission sequences that had been planned before the arrival at Mars. Changes in operations were required to adapt the mission to the phenomena occurring on the planet. However, the planet assumed a more normal appearance toward the end of January, and it was possible to map systematically a major portion of the surface.

The results of the first month's orbital operations were analyzed and preliminary results were published.(38) The major items covered in the report were the dust storm, photography of the south polar region, and photography of Nix Olympic and the W-cloud regions. It was estimated that the dust had a vertical optical thickness of about unity, and that the top of the dust cloud lay about 50 km above the surface.

Further analysis of the data was continued through the quarter. A technique was developed to use spacecraft tracking and pointing data to predict the location of the limb. This technique will be used in conjunction with existing JPL programs to plot automatically the brightness across the limb of the planet. The entire procedure will be useful in studying the time history of the dust storm, particularly its height above the surface.

Work continued on the development of a multiple scattering program that is required for the analysis of Mariner data. Preliminary results have been obtained.(39) Details of the computer program have been published.(40)

The technical summary of work performed under this task order was issued on March 31, 1972.(41)

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(38) "Mariner 9 Television Reconnaissance of Mars and Its Satellites: Preliminary Results," Masursky, et al, Science, 175, 294 1972.

(39) Multiple Scattering Calculations for Spherical Atmospheres, E. N. Shipley, paper to be presented to the American Physical Society.

(40) A Computer Program for Carrying Out Multiple Scattering Calculations in a Spherical Atmosphere, Memorandum for File, E. N. Shipley, March 31, 1972.

(41) Technical Summary of Work Performed Under Task Order 35, Analysis of Haze Effects on Martian Surface Imagery, E. N. Shipley, January 1, 1969 through March 31, 1972.

ENGINEERING SUPPORT

Computing Facility

The operation of the Univac 1108 computer with the Exec 8 multi-programming system continued until March 31, 1972. The computer usage for the final quarter for NASA work is estimated at 300,000 charge units, including approximately 5600 charge units used by NASA Headquarters personnel.

LIST OF REPORTS AND MEMORANDA

(List in Order of Report Date)

This index includes technical reports and memoranda reported during this period covering particular technical studies.

The memoranda were intended for internal use. Thus, they do not necessarily represent the considered judgment of Bellcomm which is reflected in the published Bellcomm Technical Reports.

TITLE	DATES
Technical Summary of Work Performed Under Task Order 35, Analysis of Haze Effects on Martian Surface Imagery, E. N. Shipley.	January 1, 1969 through March 31, 1972
Technical Summary of Work Performed Under Task Order 36, Manned Space Flight Experiment Program Studies, W. W. Elam, G. T. Orrok.	January 1 through December 31, 1971
Technical Summary of Work Performed Under Task Order 37, Advanced Technology, H. S. London, G. T. Orrok, J. A. Schelke.	January 1 through December 31, 1971
Photographic Coverage on Apollo 16, Memorandum for File, W. L. Piotrowski	January 18, 1972
Analytic Modeling of an Aerobraking Pass, Memorandum for File, R. N. Kostoff.	January 19, 1972
Two Computer-Generated Views of the Descartes Landing Area from the LM During Descent, Memorandum for File, S. C. Wynn.	January 19, 1972
AS-511 S-IVB Performance Prediction Compared to AS-510, Memorandum for File, K. P. Klaasen.	January 20, 1972
The Brightness Temperature of the Air-Sea Interface at Microwave Frequencies, TM-72-1011-1, C. C. H. Tang.	January 21, 1972
Interaction of the Solar Wind with a Planetary Ionosphere, TM-72-2015-1, W. R. Sill, J. L. Blank (Western Electric Research Center).	January 25, 1972

TITLE	DATE
Use of Shuttle for Life Sciences, Memorandum for File, R. E. McGaughy.	January 25, 1972
Earth Applications and the Space Shuttle, Memorandum for File, W. W. Elam.	January 25, 1972
Use of Shuttle in Sortie Mode, TM-72-1011-3, G. T. Orrok.	January 31, 1972
Lunar Surface EVA Photography of Hadley Rille - Contrast as a Constraint, TM-72-2015-2, H. W. Radin.	February 1, 1972
Visibility of Sugarloaf During Traverse at Descartes, Memorandum for File, H. F. Connor.	February 7, 1972
Visibility of Northern Areas at Descartes from a Proposed Excursion During EVA I, Memorandum for File, H. F. Connor.	February 15, 1972
Skylab Electrical Power System Performance for the Earth Resources Mode, Memorandum for File, D. P. Woodard.	February 15, 1972
An Empirical Method for Determining the Lunar Gravity Field, TM-72-2014-1, A. J. Ferrari	February 28, 1972
Long Term Trajectory Generator with VARPAR, Memorandum for File, R. C. Purkey.	February 28, 1972
Effects of LRV Parking Attitude on Thermal Performance of the LCRU and LRV Batteries, Memorandum for File, A. S. Haron.	February 29, 1972
Computer-Generated Views Showing Surface Brightness Variations of the Descartes Landing Area from the LM During Descent, Memorandum for File, S. C. Wynn.	February 29, 1972
Additional Computer-Generated Panoramas of the Descartes Terrain and an Index to all Available Scenes, Memorandum for File, G. S. Taylor.	March 3, 1972
User's Guide for SACSIM - Skylab Attitude Control Simulation, Memorandum for File, R. W. Grutzner.	March 8, 1972
Thermodynamic Flow of Super-Critical Oxygen in Zero-Gravity, TM-72-1022-1, V. Thuraisamy.	March 20, 1972

TITLE	DATE
Effects of Poor Trafficability at North Ray Crater on Apollo 16 Geology Traverses, Memorandum for File, K. P. Klaasen.	March 31, 1972
View of North Ray, Memorandum for File, S. B. Watson.	March 31, 1972
Apollo 15 LM Descent Propulsion Budgeting and Performance, Memorandum for File, W. W. Ennis.	March 31, 1972
Long Term Perturbations to the Skylab Orbit, Memorandum for File, R. C. Purkey.	March 31, 1972
Equilibrium Properties of the Skylab CMG Rotation Law, TM-72-1022-2, B. D. Elrod, G. M. Anderson	March 31, 1972
State of Voltage Breakdown Prevention in Space Flight Systems, TM-72-2034-1, W. J. Benden.	March 31, 1972
A Computer Program for Carrying Out Multiple Scattering Calculations in a Spherical Atmosphere, Memorandum for File, E. N. Shipley.	March 31, 1972
Land Landing Probability for LES Abort Following an Engine-Out, Memorandum for File, D. G. Estberg.	March 31, 1972
Investigation of CSM Water Dumps as a Possible Source of the SIDE H_2O^+ Readings of March 7, 1971, Memorandum for File, R. J. Stern.	March 31, 1972
Earthshine and Near Terminator Photography Obtained on Apollo 15, Third Lunar Science Conference Abstracts, D. D. Lloyd, J. W. Head.	1972
Geologic Conclusions from Apollo 15 Photography, Third Lunar Science Conference Abstracts, F. El Baz.	1972
Orbital Science Returns from Apollo 15, AIAA Transactions, F. El Baz.	1972
Visual Observations from Lunar Orbit, Apollo 15 Preliminary Science Report, F. El Baz, A. M. Worden.	1972
The Cinder Field of the Taurus Mountains, Apollo 15 Preliminary Science Report, F. El Baz.	1972

TITLE	DATE
Surface Disturbances at the Apollo 15 Landing Site, Apollo 15 Preliminary Science Report, N. W. Hinners, F. El Baz.	1972
Orbital Search for Lunar Volcanism, submitted to the Journal of Geophysical Research, R. R. Hodges, Jr., J. J. Hoffman, T. T. J. Yeh, G. K. Chang.	
Mariner 9 Television Reconnaissance of Mars and Its Satellites: Preliminary Results, Science, 175, 294, Masursky, et al.	1972
Multiple Scattering Calculations for Spherical Atmospheres, paper to be presented to the American Physical Society, E. N. Shipley.	1972

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